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THE BEHAVIOR OF RANGE SAFETY SYSTEM ORDNANCE FOR THE SPACE SHUTTLE WITH SIMULATED AERODYNAMIC HEATING

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Autoignition and performance tests simulating reentry temperature conditions were completed using the RSS ordnance in a simulated flight configuration. Temperature measurements were made at several locations within the RSS to provide data for thermal model correlation. Autoignition resulted in detonation and functioning of the RSS with destruction (cutting) of the simulated ET wall in five tests. In six tests, thermal explosions resulted with no cutting action. Autoignition of HMX in the linear shaped charge configuration occurred at ~470°F compared to the reported value of

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585°F for the bulk explosive. Autoignition of the complete RSS (CDF-LSC assembly) occurred in the range of 390°-450°F. It appears that autoignition of the PETN tip at the end of the CDF is not a factor in the transfer of explosion or detonation to the linear shaped charge, and HNS in the CDF is safe to ~1000°F.

FOREWORD

An explosive system using linear shaped charges was designed to destruct the External Tank of the Space Shuttle on command of the Range Safety Officer, if circumstances made it necessary. This system can provide rapid dumping of the liquid oxygen and hydrogen in their separate tanks within the External Tank, at a time and in a way that minimizes mixing of the fuels and hence minimizes the blast potential of the mixed fuels.

A major question existed as to whether an autoignition of the explosive system due to rapid aerodynamic heating could produce an unwanted destruct performance during a flight configuration.

This study showed that autoignition of the explosive within the ordnance assembly would lead to premature detonation and destruct system action. As a result, temperature limits below which operational range safety ordnance should be maintained by insulation, system design and installation were recommended.

The Naval Surface Weapons Center conducted destruct system design and analyses for the National Aeronautics and Space Administration, George Marshall Space Flight Center under NASA-Defense Purchase Request H-13047B dated 15 May 1978 with Admendment 11 added on 2 April 1980 to include this report and study.

The authors are indebted to J. A. Roach of the Marshall Space Flight Center who suggested this study and coordinated efforts in the analyses. N. Snowden, B. Snowden, B. Holland, and C. Goode of NSWC (WOL) assisted in the experimentation.

J. PROCTOR
By direction

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INTRODUCTION

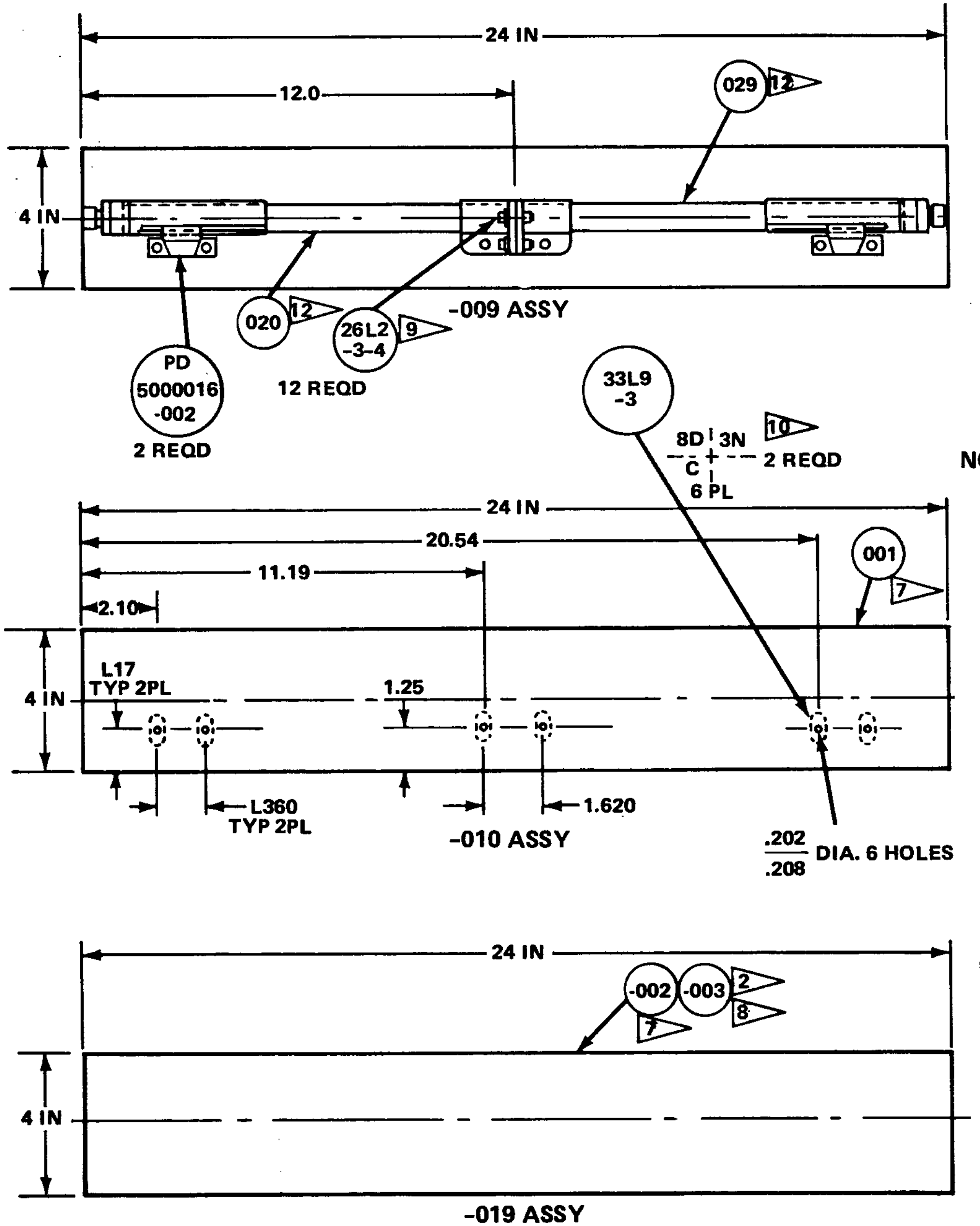
The behavior of the explosive in a heated ordnance device is an important consideration for both safety and performance reasons. Catastrophic effects from a premature ignition resulting from the exposure of the Range Safety System (RSS) of the Space Shuttle to elevated temperatures during reentry must be prevented. An autoignition of the RSS explosive assembly (from aerodynamic heating) causing External Tank (ET) break-up above 250,000 feet would result in an unacceptably large debris footprint. Operational temperature limits derived from the thermal data (Table 1) must be maintained by using suitable insulation to assure an operational RSS until Main Engine Cut-off (MECO) and no autoignition until the orbiter and the ET are separated $\sim$4 miles.

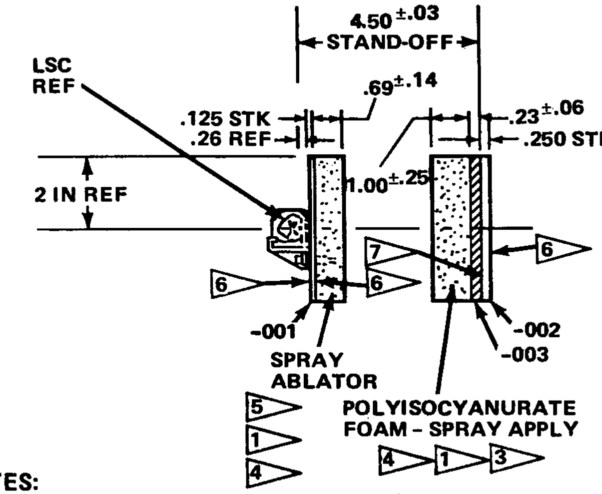
Little is known about the autoignition or "cook-off" characteristics of the materials in the RSS explosive train, i.e., the Confined Detonating Fuze (CDF) and Linear Shaped Charge (LSC), at the expected elevated temperatures and rates of heating prior to MECO. The literature values of the autoignition temperatures for PETN (285°F) or HNS ($\sim$1000°F) in the CDF and HMX ($\sim$585°F) in the LSC may be influenced by the size of the test sample rate of heating, confinement, etc. Also, there are questions as to whether or not an autoignition at elevated temperatures in the RSS would produce a destruct performance (cut) of the ET in flight configuration (Figure 1). Therefore, a series of autoignition tests were performed in an explosive bombproof chamber at the Naval Surface Weapons Center to determine autoignition and performance characteristics of the above explosives in a thermal environment which simulated the rate of heating of the RSS ordnance in a flight configuration. The heating rates were based on calculated temperature profiles (Figure 2) for the RSS cable tray ordnance in flight.

TABLE 1 THERMAL PROPERTIES OF RSS EXPLOSIVES

Explosive	Specification Number	TMD g/cm^3	Nominal Loading Density g/cm^3	Operational Temperature Limit* $^oC/^oF$	Melting Point $^oC/^oF$	Coefficient of Thermal Expansion $10^6 in \cdot in^{-6} {}^oF$	Specific Heat $(cal/g \cdot {}^oC)$	Thermal Stability cm^3 gas evolved/48 hr
PETN	MIL-P-387A	1.77	1.77	121/250	141/286	76.5-89.9	0.28	0.21 at 212°F
HMX	MIL-N-45444	1.90	1.90	177/350	283/541	50.4	0.25	.1 at 212°F
HNS	WS-5003	1.79	1.79	177/350	318/605	92.0	0.40	First 20 min. 0.5cc/g/20 min at 500°F

*Insulation in the ET is designed to maintain the RSS ordnance below these temperatures.





NOTES:

1. MACHINING OF FOAM PERMISSABLE TO OBTAIN CONFIGURATION REQMTS.
2. BOND ABLATOR MATERIAL PER STP 8005, TYPE 2.
3. APPLY SOF1 PER STP 1512. NO SUBSTRATE FINISH REQMT.
4. AFTER FINAL TRIMS AND TPS CLOSEOUTS, TOP COAT ALL TPS SURFACES PER STP 3011 UNLESS OTHERWISE SPECIFIED.
5. APPLY MATERIAL PER STP 1506.
6. CHEM FILM PER STP 3001, CLASS 1A.
7. CLEAN AND DEOXIDIZE ORDNANCE TEST PLATES PER STP 5003, AND STP 5006, METHOD 1. USE SOLUTION NO. 3 WITHOUT 10% NITRIC ACID. APPLY EPOXY PRIMER PER STP 3003, TYPE 1 WITHIN FOUR HOURS AFTER CLEANING.
8. MOLD MATERIAL PER STP 1508, TYPE 1.
9. INSTALL FASTENERS PER STP 2014.
10. INSTALL CSK HEAD RIVETS PER STP 2003.
11. BREAK ALL BURRS & SHARP EDGES.
12. (-020, -029) OF -009 ASSY IDENTICAL TO PD5000016 -019 ASSY EXCEPT AS NOTED:
    - A. DELETE ANODIZE ON ALUMINUM COMPONENTS.
    - B. DELETE PRIMER COAT ON COPPER SHEATH.
    - C. ELIMINATE CASTINGS. USE WELDMENTS OR BARSTOCK-MACHINED, BUT SIMULATE WEIGHT OF CASTING.
    - D. ELIMINATE PD5000016-020 STAND-OFF CLAMPS.
    - E. DELETE ALL TESTS EXCEPT FINAL X-RAY.

FIGURE 1 DIMENSIONAL DETAILS OF LSC TEST ASSEMBLY

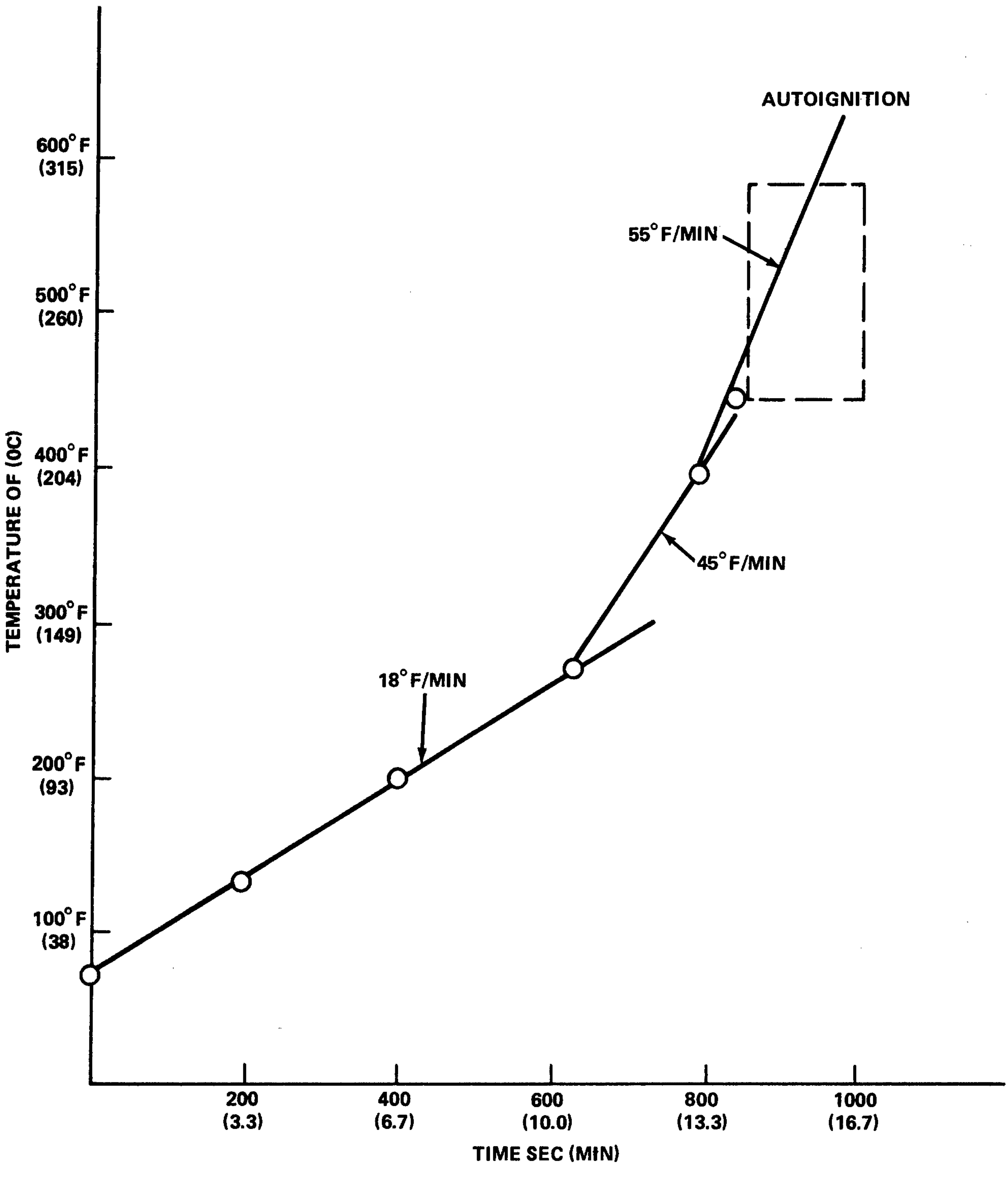


FIGURE 2 CABLE TRAY ORDNANCE TEMPERATURE HISTORY (CALCULATED BY MARTIN MARIETTA CORP.)

OBJECTIVES OF THE TEST PROGRAM

The objectives of the test program were to provide autoignition data on potential deflagration-to-detonation transitions in the RSS explosive train for the following conditions:

a. PETN (operational temperature limit, 250°F) in the CDF tip autoignites while the LSC is below its operational temperature limit (350°F). The objective was to determine if PETN autoignition would produce a transfer of detonation to the HMX in the LSC.

b. HMX in the LSC autoignites. The objective was to record and determine whether the HMX autoignition produces detonations and/or cutting performance of the LSC.

c. HNS in the CDF autoignites. The objective was to determine the autoignition temperatures of HNS and the possibility of detonation transfer to the CDF tip and the LSC.

d. The CDF autoignites upstream of the LSC with sections of unheated operational CDF between the autoignition point and the LSC. The objective was to determine whether autoignition could lead to detonation transfer from hot CDF to cold CDF (or vice versa) and RSS performance.

e. Evaluate RSS performance at elevated temperatures.

In addition to the heating tests, several tests were made at the ambient temperatures to check the cutting performance of the LSC in the flight configuration and to measure the detonation velocity of HMX. The detonation velocity measurements were a check on the core loading density of HMX in the LSC. All tests were designed to measure LSC performace. Performance is defined as the ability of the LSC after RSS autoignition to cut through an aluminum plate which simulates the ET wall in the cable tray-ET flight installation.

TEST ARRANGEMENTS

The test samples consisted of a 12-inch length of copper-sheathed LSC loaded with 750 grain/ft HMX, and ~30-inch length of the CDF assembly containing a PETN tip connector. Figure 2 gives dimensional details of the LSC test assembly. Figure 3 shows the CDF assembly.

The CDF-LSC train was mounted on an aluminum plate (010 assembly, Figure 2) with flight configuration brackets to simulate the cable tray installation. A second aluminum plate (019 assembly, Figure 3) was positioned below the simulated cable tray plate to evaluate potential damage to the ET skin from effects of LSC autoignition. The aluminum plates were insulated and mounted as in the flight configuration (see Figure 4).

The simulated cable tray and ET wall plates were located in slots cut into the sides of two aluminum plates (see Figure 4) which formed heating panels. One thousand watts strip heaters, 26 inches long, were mounted on the panel. Two or four heaters were used in pairs and mounted on the inside or outside of the panels, depending on the desired heating rate. The heating (autoignition-performance test) arrangement (Figure 4) with the LSC-CDF assembly in place was placed in a 12-inch diameter, 36-inch long cylindrical pipe which then was filled with sand. Figures 5 and 6 give pictorial view of the test arrangement.

Temperatures were measured by thermocouples which were located on the ordnance and within the cable tray simulant. These measurements supplied data for thermal model correlation calculations. Thermocouples were located on the LSC sheathing, PETN connector nut, CDF cord and connector bracket, LSC support bracket, LSC-CDF connector housing, air in the heating rack, and on the simulated cable tray surface.

Holes of a 1/16-inch diameter were drilled through the LSC sheathing at 1-inch intervals to provide ionization gaps for pin oscilloscope probes used in the detonation velocity tests.

A heat-resistant cement (Saureisen) was used to hold the thermocouples and pin probes in place. The thermocouple outputs were fed into multichannel Brown recorders which reproduced the temperature-time profiles at the various thermocouple locations.

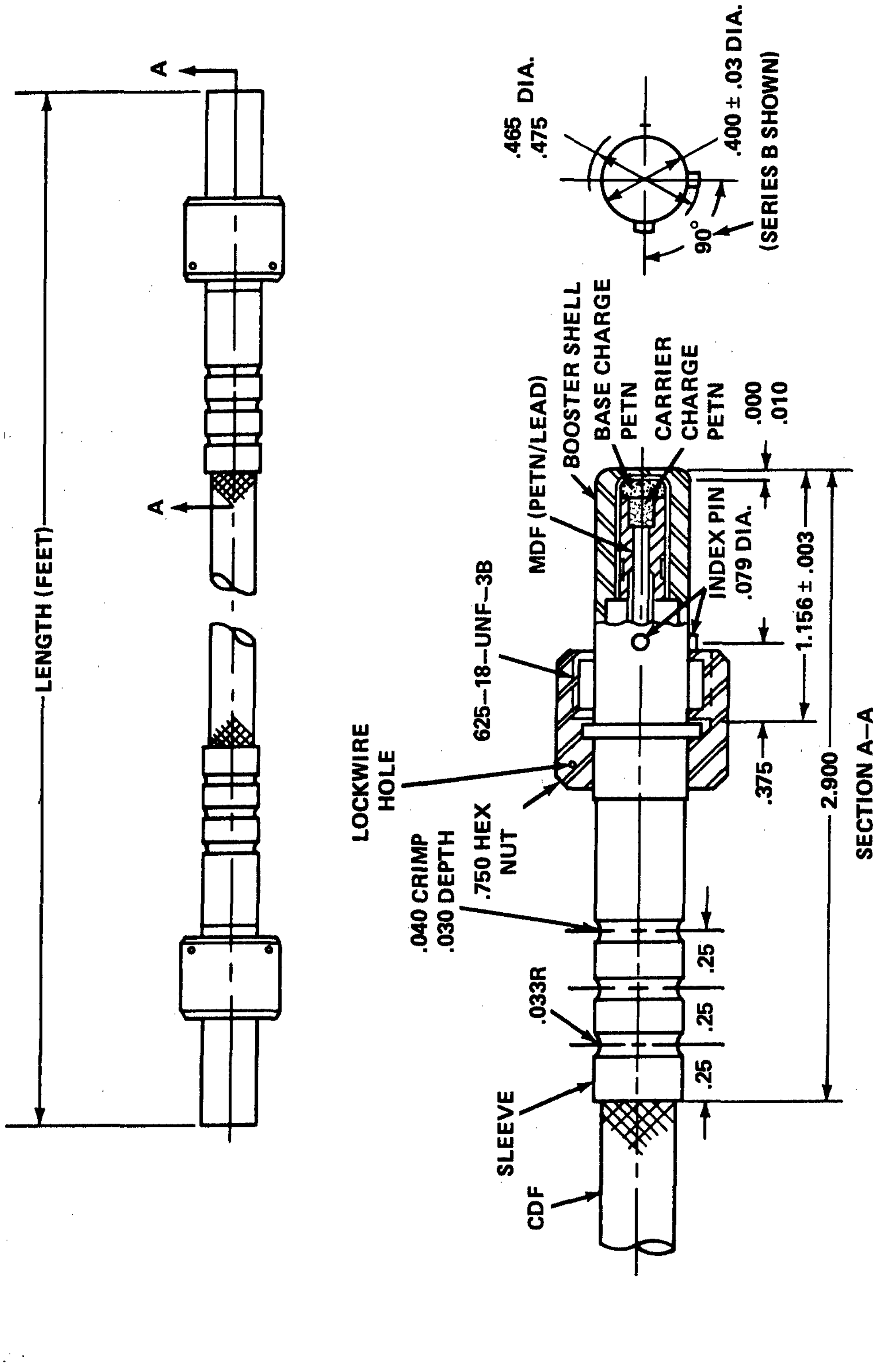


FIGURE 3 CDF ASSEMBLY (ENSIGN BICKFORD)

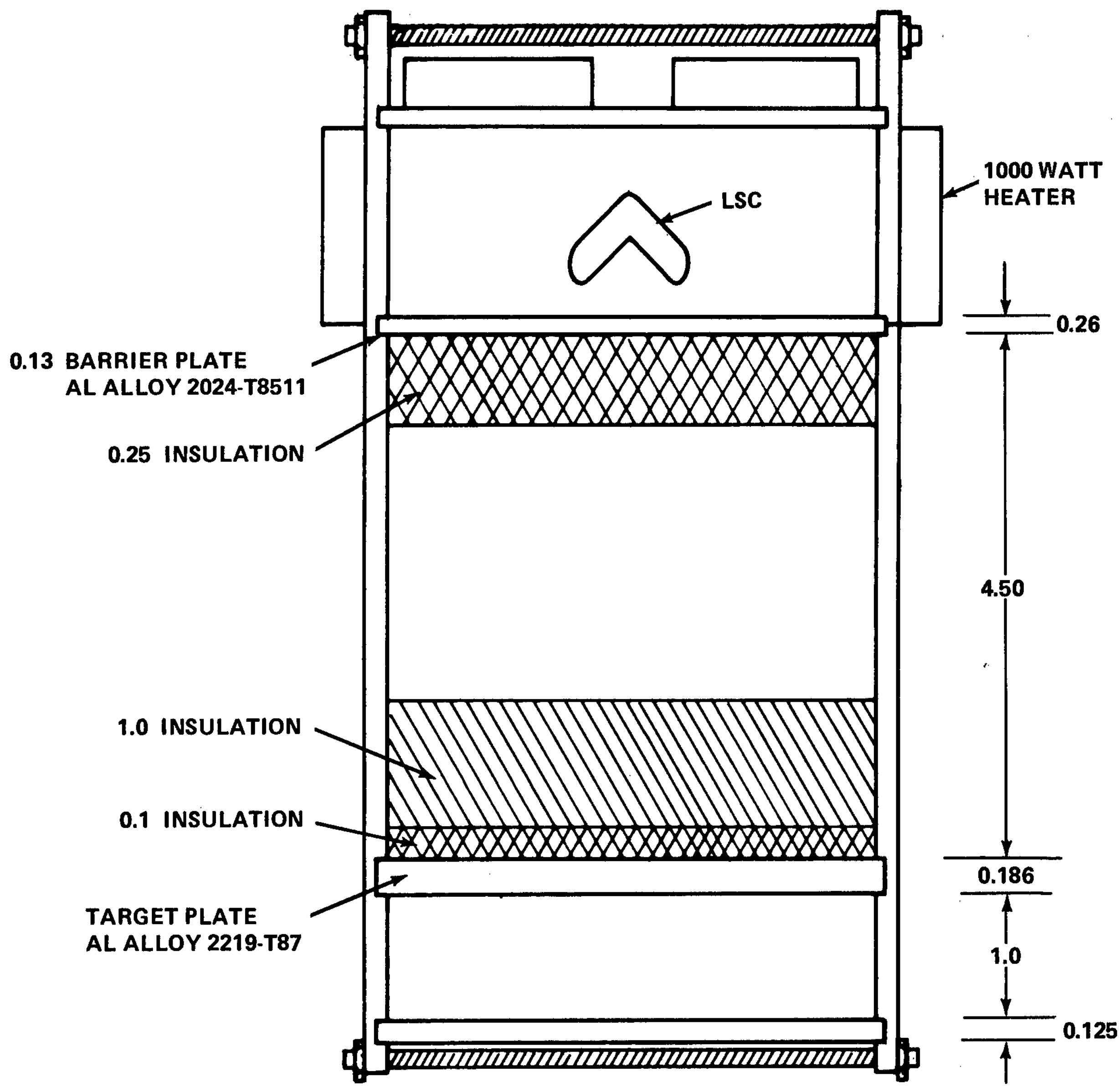


FIGURE 4 SIMULATED CABLE TRAY-ET ARRANGEMENT FOR AUTOIGNITION AND LSC PERFORMANCE TESTS

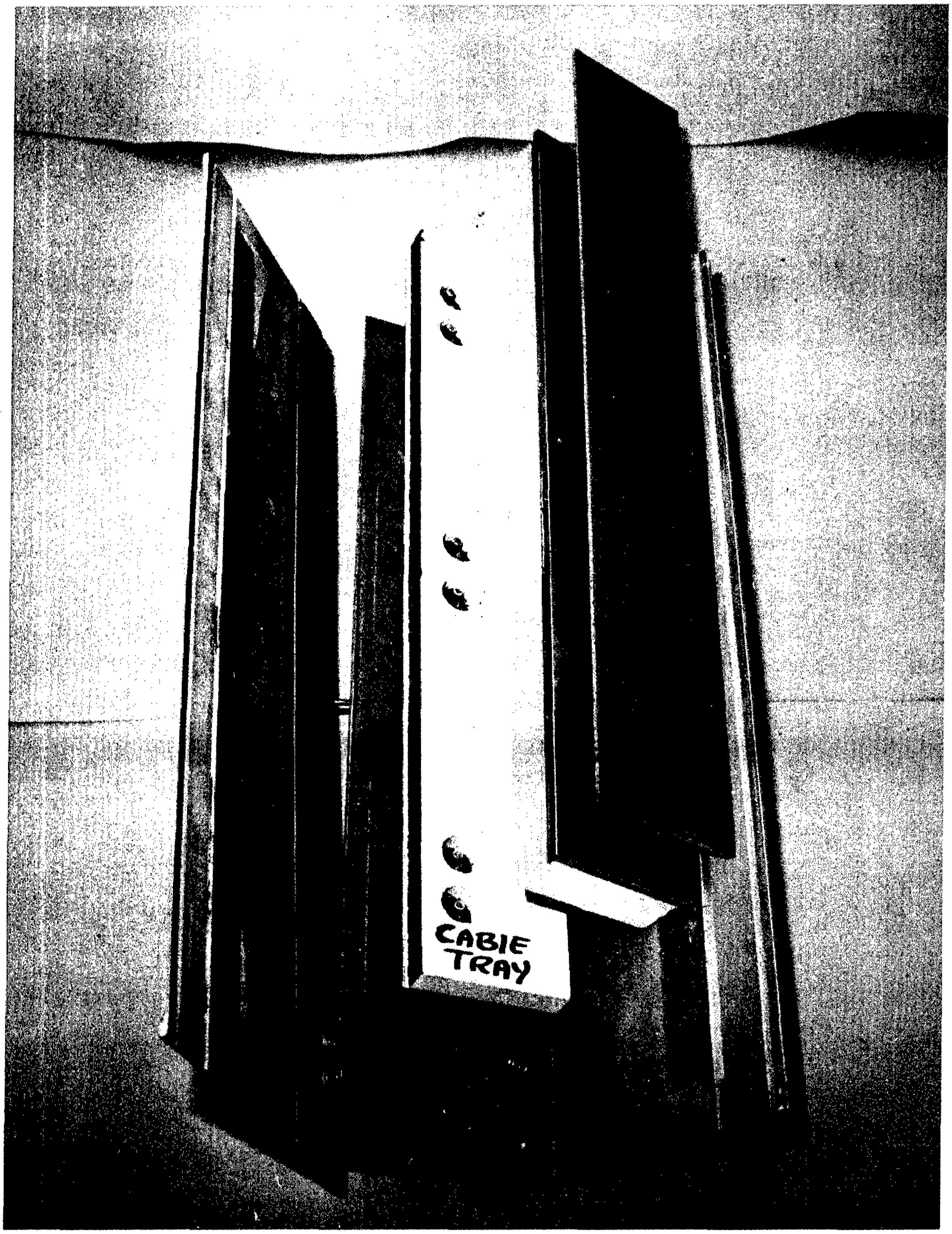


FIGURE 5 PICTORIAL VIEW OF THE TEST ARRANGEMENT

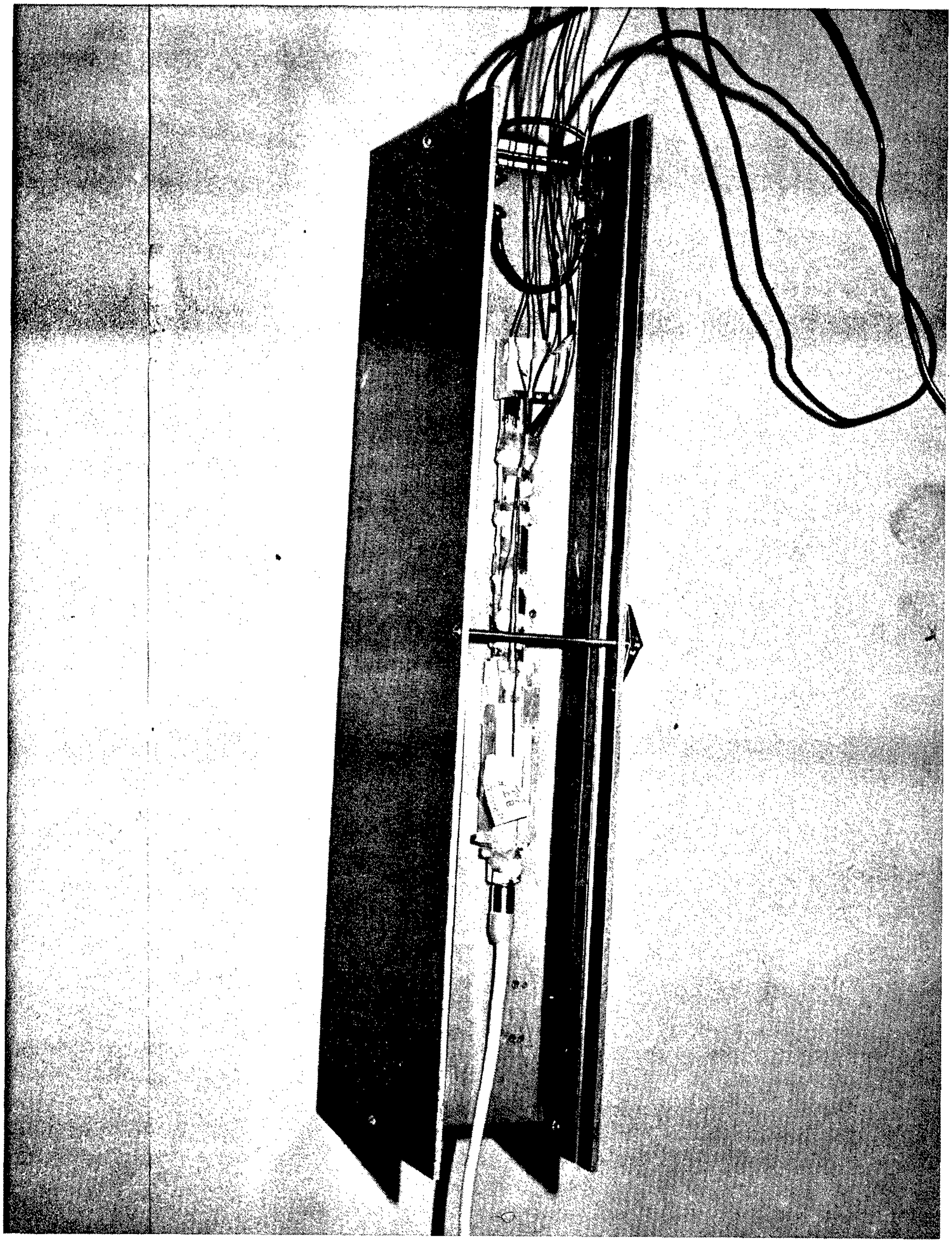


FIGURE 6 PICTORIAL VIEW OF THE TEST ARRANGEMENT (ASSEMBLED) SHOWING THE CDF-LSC TEST ASSEMBLY

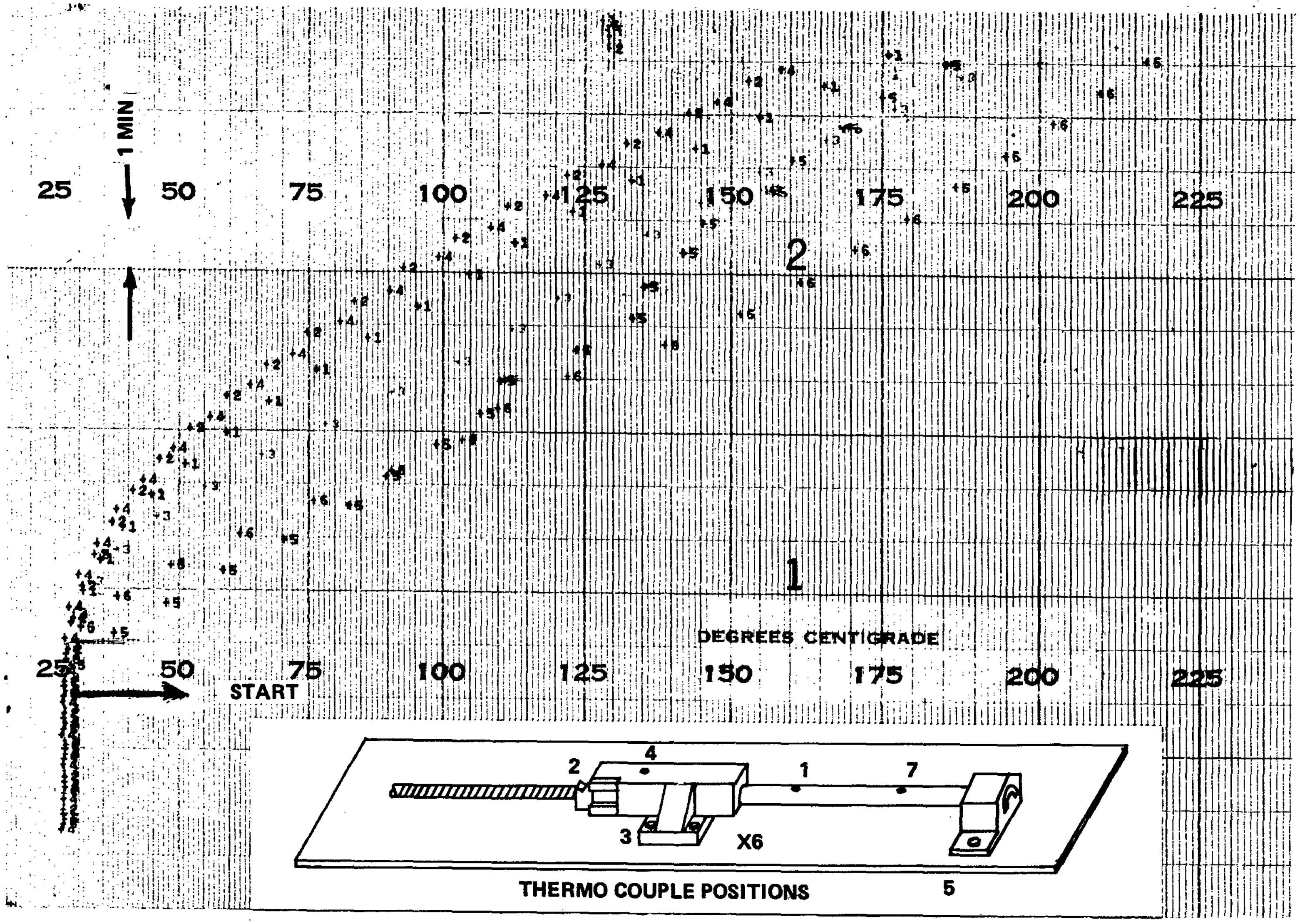
RESULTS

Figure 7 is a typical temperature-time recording of the RSS heating to the point of autoignition. Generally when autoignition occurred, there was a loud "pop" or "bang," which was somewhat muffled because the RSS assembly was covered with sand. (In some tests, there were two unexplained "bangs.") Thermocouple behavior became erratic almost instantaneously due to loss of contact, flame reaction, shock, etc., and the recording went "off-scale." Thermocouple recordings from points on the LSC sheathing were used to estimate the autoignition temperature. Table 2 is a summary of the final temperatures recorded at the various thermocouple positions on the RSS for tests where autoignition occurred. The test results have been grouped according to the program objectives in Tables 3, 4, 5, and 6 and are discussed below.

Table 3 contains the results of testing the flight configuration's performance in response to a firing stimulus (No. 6 detonator) at ambient temperature. Test Nos. 1 and 6 verified the capability of the LSC to cut the ET wall. Figure 8 shows the damaged condition of the simulated flight configuration as recovered from Test No. 1. Note that both the cable tray and ET wall were severed. In Test Nos. 7 and 8, the detonation velocity of the HMX load in the LSC was measured. Values of 8660 m/sec and 8600 m/sec, respectively, were obtained. These measurements were not made in a simulated flight configuration; hence, no cable tray or ET wall cuts were obtained. In Test No. 12 of Table 3, the flight configuration was heated to 380°F with an unheated, ~2-foot length of CDF outside the oven. This CDF length had a detonator attached, which was pulsed when the temperature of the LSC-CDF reached 380°F. In contrast to the results in Test Nos. 1 and 6, detonations did not transfer through the heated CDF length and PETN connector to the LSC.

Table 4 lists the results of autoignition tests of the flight configuration when it is heated at rates from ~40°F/minute to ~70°F/minute. These heating rates correspond to conditions occurring ~10 minutes to 17 minutes in flight (see Figure 2) and were rapidly attained in the oven arrangement without inconvenient apparatus adjustments.

In test Nos. 2, 3, and 13 complete detonation occurred, and the jetting fragments from the LSC severed the simulated cable tray and the ET-wall located 4.5 inches below the cable tray. In none of these tests was detonation transferred back into the CDF outside the oven.



THERMO COUPLE POSITIONS: 1, 7–LSC, 2–CDF NUT, 3–CDF-BRACKET, 4–CDF-LSC CONNECTOR, 5–OVEN, 6–CABLE TRAY BOTTOM

FIGURE 7 TEMPERATURE-TIME RECORDING FOR TEST NO. 12

TABLE 2 SUMMARY OF RSS TEMPERATURES AT AUTOIGNITION

Thermocouple Location

Test No.	Oven (air) (°F)	PETN Connector Nut (°F)	CDF/LSC Bracket (°F)	Cable Tray Bottom (°F)	LSC Sheathing (°F)	LSC/LSC Bracket (°F)
2	581	-	479	426	455-469	-
3	545	479	-	509	426-437	509
4	545	473	545	-	484-489	489
5	559	489	504	563	500	532
9	520	-	414	433	410	437
10	>500	383	380	534	451	-
13	545	459	437	507	444	-
14	550	428	-	550	496-527	518
15	>570	455	445	-	435	536
16	>570	464	496	570	464-489	496
19	>570	-	410	489	440	-
20	>570	-	-	-	450	-

TABLE 3 FLIGHT CONFIGURATION PERFORMANCE TO INITIATION STIMULUS AT AMBIENT TEMPERATURES

Test No.	Explosive Train	Reaction Type	Cable Tray Result	ET Wall Result	Remarks
1	No. 6 Detonator and CDF and LSC	Detonation	Cut	Cut	Ambient Temp. 90°F
6	No. 6 Detonator and LSC	Detonation	Cut	Cut	Ambient Temp. 90°F
7*	No. 6 Detonator and CDF and LSC	Detonation	-	-	D = 8600 m/sec
8*	No. 6 Detonator and CDF and LSC	Detonation	-	-	D = 8600 m/sec
12	No. 6 Detonator and CDF and LSC	Explosion	No Cut	No Cut	Heated to 380°F then the explosive train was initiated

*Tests were not done in simulated flight configurations i.e., without cable tray and ET wall.

TABLE 4 FLIGHT CONFIGURATION - THERMAL SENSITIVITY TESTS

Test No.	Heating Rate (^oF/min)	T_{cu}* (^oF)	T_o* (^oF)	Reaction Type	Cable Tray Result	ET Wall Result	Remarks
2	68.4	460-470	580	Detonation	Cut	Cut	
3	39.6	430-440	550	Detonation	Cut	Cut	
9	37.8	390-410	520	Low Order Detonation	Cut	No Cut	
10	37.8	450	570	Explosion	No Cut	No Cut	CDF-LSC Connector insulated
13	70.0	444	545	Detonation	Cut	Cut	
14	42.8	510	560	Explosion	Split	No Cut	Blast Split Cable Tray

*T_{cu} - LSC Sheathing Temperature at Autoignition

**T_o - Oven (air) Temperature at Autoignition

TABLE 5 THERMAL SENSITIVITY TESTS*

Test No.	Heating Rate (^{o}F/min)	T_{cu}* (^{o}F)	T_{o}* (^{o}F)	Reaction Type	Cable Tray Result	ET Wall Result	Remarks
4	39.6	484-490	550	Explosion	No Cut	No Cut	
5	40.0	500	560	Explosion	No Cut	No Cut	
15	77.0	545	570	Detonation	Cut	Cut	24" LSC
16	41.0	464-490	570	Explosion	Cut	No Cut	24" LSC
19	40.0	440	570	Explosion	Cut	No Cut	LSC** Confined
20	40.0	450	570	Explosion	No Cut	No Cut	LSC** Confined

*T_{cu} - 12-inch long except as noted -- No CDF

**T_{o} - Tested as Received

TABLE 6 CDF - THERMAL SENSITIVITY TESTS

Test No.	Heating Rate (^oF/min)	T_{cu} (^oF)	T_o (^oF)	Reaction Type	Remarks
11	80	-	400	Detonation**	CDF heated to 1000^oF then cooled to 400^oF and initiated by No. 6 Detonator
17	70	-	500	-	PETN Tip Connector No recording of reaction Temperature connector was bulged
18	70	-	550*	Explosion	PETN Tip in contact with steel block No Dent

*Steel Block Temperature
**Detonation propagated from detonator through one end of CDF into oven, but stopped before reaching the other end.

FIGURE 8 SIMULATED FLIGHT CONFIGURATION RECOVERED AFTER TEST NO. 1. PERFORMANCE TEST OF LSC ASSEMBLY AT AMBIENT TEMPERATURE,90°F

In Test No. 9, the flight configuration was heated at the rate of 37.8°F/minute, and autoignition occurred when the LSC sheathing was at a temperature between 390°F and 410°F. The autoignition produced what is considered a low-order detonation since only the cable tray was cut, and the LSC sheathing was not totally fragmented. A high-order detonation propagating at ~8600 m/sec in HMX produced cuts in the cable tray bottom and ET wall with total sheathing fragmentation.

Autoignition in Test Nos. 10 and 14 only resulted in explosions. In Test No. 10, the CDF-LSC connector and bracket were insulated by ~0.5 cm thick cover of insulation. Test No. 14 used the normal flight configuration without the insulation. The simulated ET wall in these tests were not cut. This result was considerably different than the damage produced in Test Nos. 2 and 3 where autoignition led to detonation. (Figures 9 and 10 show the recovered simulated flight configurations after these tests. Note that in Test Nos. 2 and 3, the cable trays were fragmented and a ~5-inch long section of the ET wall plate was severed.) The temperatures at which autoignition occurred in Test Nos. 10 and 14 were 450°F and 510°F, respectively. The value 510°F is perhaps high since in the five other tests in Table 3, no autoignition occurred when the LSC sheathing temperature was ~440°F. Table 5 lists the results of autoignition tests of the LSC without the CDF. These tests were performed to establish whether autoignition in the PETN tip of the CDF is necessary for detonation and cutting by the LSC. Six tests were made with only the LSC. Only one detonation occurred, but five explosions resulted. (Figure 11 shows the test configuration recovered from an explosion with no cuts.) In the only detonation, Test No. 15, the LSC length was increased to 24 inches by using an LSC/LSC connecting bracket to butt two 12-inch lengths of LSC together. Autoignition in this test led to detonation with cutting of the cable tray and ET wall. In this test the rate of heating, 77°F/sec, was higher than in the other tests, and the final heating temperature at autoignition was 545°F. When the test was repeated with a similar length of LSC (Test No. 16), but at a heating rate of 41°F/minute, only an explosion resulted at a lower temperature (464°F - 490°F).

Test Nos. 19 and 20 were made to check the effect of confinement by using 12-inch long LSC assemblies as received from the contractor. The LSC's as received were partially contained in a 3-inch long cylindrical section forming a part of the LSC mounting bracket. This cylindrical section increased the confinement of the explosive in the LSC, but also decreased the exposed cutting length of the LSC. All tests except Test Nos. 19 and 20 were performed using LSC which had the cylindrical section removed. Despite the increased confinement, the autoignitions occurring in Test Nos. 19 and 20 were considered thermal explosions. In each test the force of the autoignitions was sufficient to damage (cut) the simulated ET wall by LSC action. Also, the LSC sheathing was recovered without any indications of jetting.

Three tests listed in Table 6 were run to determine the thermal sensitivity of the CDF assembly. In none of the tests were the recordings sufficiently sensitive to pinpoint the autoignition temperature of either PETN or HNS. Normally, when autoignition occurred, it was indicated by erratic or sudden "off-scale" thermocouple recording. In Test No. 11, the central 20 inches of a 40-inch long section of CDF was heated to 1000°F and then allowed to cool to 400°F. Both ends of the CDF, which are unheated, had end tip assemblies and

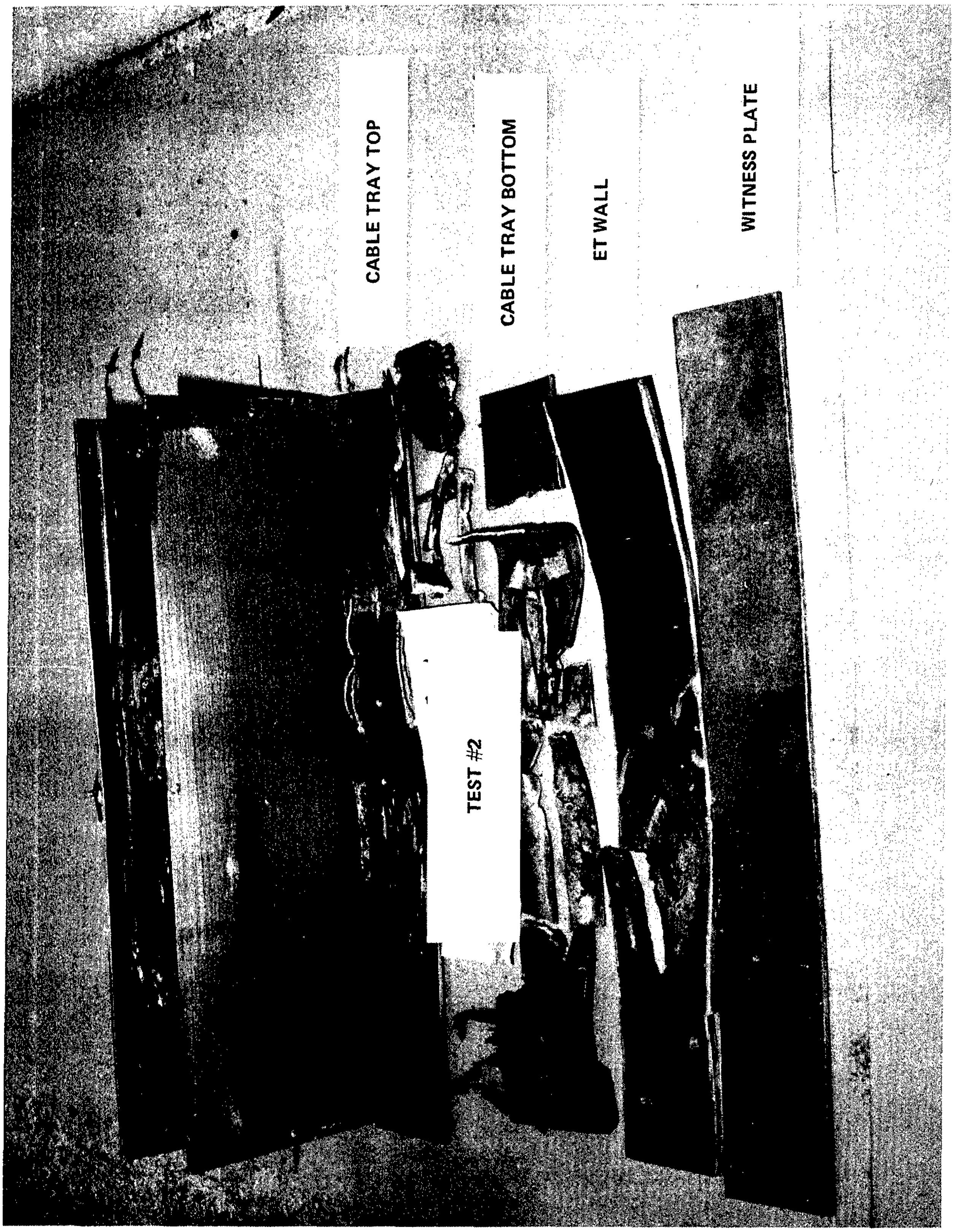


FIGURE 9   RECOVERED SIMULATED FLIGHT CONFIGURATION AFTER AUTOIGNITION TEST NO. 2

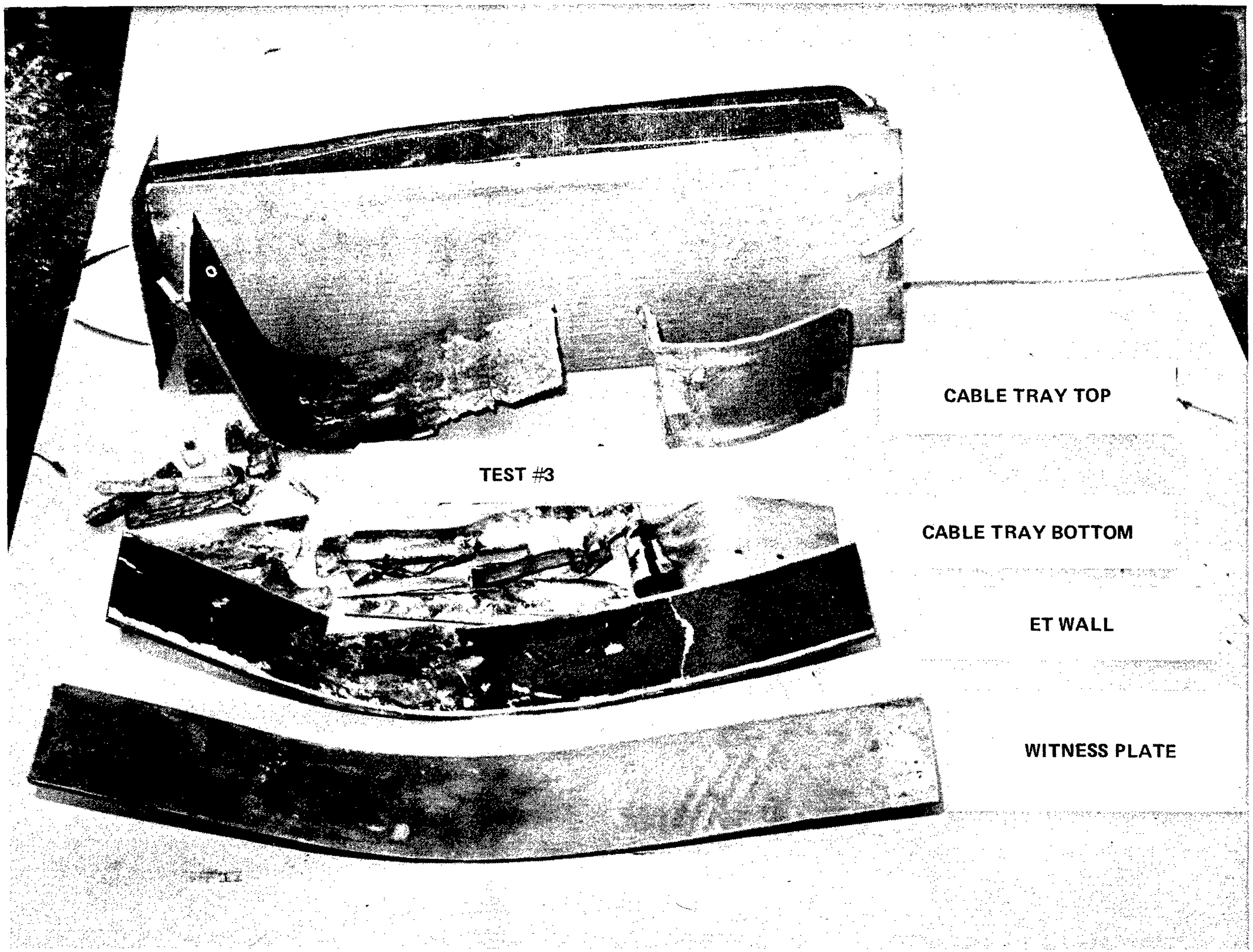


FIGURE 10 RECOVERED SIMULATED FLIGHT CONFIGURATION AFTER AUTOIGNITION TEST NO. 3

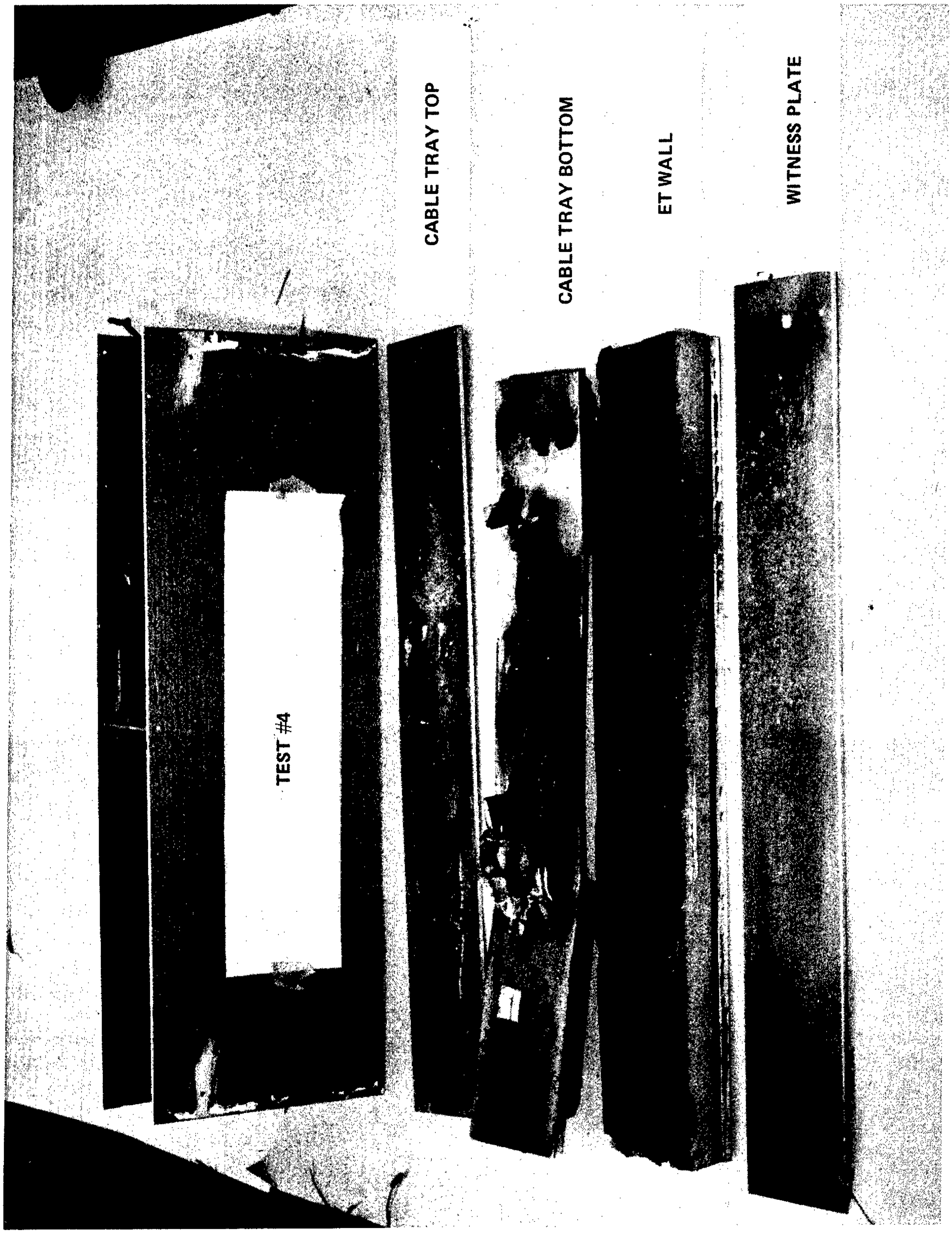


FIGURE 11 RECOVERED FLIGHT CONFIGURATION AFTER AUTOIGNITION TEST NO. 4

one tip had a No. 6 detonator attached. When the CDF had cooled to 400°F, the detonator was fired and detonation propagated into the fuze section within the oven. When the recovered fuze was examined, it was observed that the PETN tip connector on the other end had not bulged as was typical of detonation. The heated cord was separated, and it was noted that the HNS column within the silver sheathing was broken into several sections with some discoloration apparent. This result indicated detonation wave propagation had stopped at some point within the heated section of CDF.

Test No. 17 was an autoignition test which was done with the CDF without detonator initiation. The CDF with a PETN tip connector was heated to ~500°F and was recovered with the tip bulged, indicating autoignition had occurred. In Test No. 18, the PETN tip connector was placed in contact with a steel block within the oven to determine the output on autoignition by a dent test. Although the connector was bulged slightly, no dent in the block was observed.

DISCUSSION

Autoignition of the explosive within the RSS assembly led to a buildup to detonation contrary to prior expectations. This result was indicated in Test Nos. 2, 3, 9, 13, and 15 where (except in Test No. 9) the LSC jetting action cut through the simulated ET wall. There was not sufficient residual cutting action to sever the witness plate below the ET wall plate. However, the witness plate was buckled and indented, and the type of cut was similar to the results of tests in which the HMX detonation reaction had been initiated by a detonation.

The autoignition reaction result, whether an explosion or a detonation, was not dependent on the rate of heating. Only the temperature and time at which it occurred was affected slightly by the heating rate. The autoignition temperature measured for the RSS flight configuration was $\sim 450^{\circ}F$. A lower value, $390^{\circ}F$, was measured in Test No. 9 when the CDF/LSC connector was insulated. This value is considerably lower than the temperature of $585^{\circ}F$ given in the literature for HMX. Moreover, the presence of the PETN tip on the CDF with its reported lower autoignition temperature of $285^{\circ}F$ apparently had no effect on the result. For example, in tests without the CDF/PETN tip (Table 5) with the LSC only, except for the high value observed in Test 15 where detonation occurred using a longer LSC run, the average autoignition temperature was $472^{\circ}F$. It is evident that a thermal explosion such as these tests could build up to detonation in a longer RSS configuration. Since the autoignition of HMX can lead to detonation without the presence of the PETN connector, there is good evidence that a more urgent requirement is to protect the LSC by adequate insulation rather than the CDF and PETN tip. The results in Table 5 and the measured autoignition temperature indicate this conclusion. The autoignition of PETN, though occurring at a lower temperature ($285^{\circ}F$), was not capable of transferring detonation to the LSC. This result occurs perhaps because of the geometry of the explosive train or loss of material contact at the CDF/LSC interface due to PETN melting and decomposition. The conclusion is supported by the results of Test 12. Detonation failed to transfer through the CDF/PETN tip to the LSC when the RSS was heated to $380^{\circ}F$ and detonation was initiated by a detonator at the end of the CDF. An examination of the data in Table 2 and the test geometry indicates a substantial amount of heat was transmitted to the LSC via the brackets and cable tray bottom. Thermally isolating the brackets and insulating the LSC would deter the autoignition of the HMX in the LSC.

Based on the above observations, we may consider certain temperature limits below which the RSS explosive train should be maintained by suitable insulation, ordnance design, and installation. These limits are indicated in the following table (Table 7).

TABLE 7 TEMPERATURE LIMITS FOR RSS ORDNANCE

Explosive Configuration	Design Operation Limit at MECO (°F)	Autoignition Temperature (°F)	Functional Limit (°F)	Safety Margin (°F)
CDF/HNS	350	~1000	>450	650
PETN Tip Connector	250	285	<390	140
LSC/HMX	350	470	<470	120
RSS	250	390	<390	140

TERMS

Autoignition	Internal ignition of a self-sustaining chemical reaction
CDF	Confined Detonating Fuze
Detonation	Exothermic chemical reaction with supersonic energy release
ET	External Tank
Explosion	Exothermic chemical reaction with supersonic energy release
HMX	Cyclotetramethylene Tetranitramine
HNS	Hexanitrostilbene
LSC	Linear Shaped Charge
MDF	Mild Detonating Fuze
MECO	Main Engine Cut-off
PETN	Pentaerythritol Tetranitrate
RSS	Range Safety System
Sensitivity	Behavior to an ignition stimulus

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